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Association between blood pressure, measures of body composition and lifestyle factors in township adolescents, North-West Province, South Africa

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Abstract

Risk factors for development of cardiovascular disease develop early in life and track into adulthood. This study investigated the relationship between blood pressure (BP) and measures of body composition in adolescents. The study participants were 307 adolescents. Blood pressure (BP) and anthropometric parameters: (weight, height, waist (WC) and hip circumferences), triceps skinfolds (TSKF) and subscapular (SSKF) skinfolds were measured. From these parameters, body mass index (BMI), waist-hip ratio (WHR), subscapular skinfold/ triceps skinfold (S/T) ratio and subscapular skinfold/ subscapular skinfold + triceps skinfold (S/ST) ratio were calculated and used as measures of body composition. In addition, percentage body fat was determined using air displacement plethysmography and the BODPOD scale. Pre-hypertension/hypertension was observed in 21.3% of the girls and 33.1% of the boys. No gender differences in BP were observed. Twenty-five (8.1%) of the children were overweight/obese and the prevalence in girls was higher than in boys (X^2=6.08, p=0.048). In girls systolic blood pressure (SBP) was predicted from age, WC and TSKF while in boys it was predicted from height, TSKF and SSKF. No significant association was found between blood pressure, BMI and lifestyle factors. The study concluded that SBP in adolescents correlates with anthropometric parameters. In girls, peripheral fat was strongly related to SBP, while in boys centrally located fat showed strong association with SBP. WC rather than WHR correlated positively with SBP in both genders.

Keywords: Anthropometry, body composition, blood pressure, township adolescents.

Introduction

Several studies have shown that risk factors for cardiovascular diseases (CVD) such as hypertension, obesity and low physical activity manifest themselves as early as childhood and adolescence, as such posing a major challenge to public health policy development (Kelder, Oganian, Feldman, Webber, Parcel, Leupker, Wu & Nader, 2002). The risk factors are associated with the individual's lifestyle and habits which develop in childhood and adolescence (Lauer, Burns, Clarke & Mahoney, 1991).

Although clinical hypertension occurs less frequently in children than in adults (Sinaiko, Gillum, Jacobs Jr, Sopko & Prineas, 1982; Sinaiko, Gomez-Marin & Prineas, 1989; National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents, 2004), ample evidence now supports the suggestions that the roots of essential hypertension extend back to childhood. Of particular importance is the documentation that elevated blood pressure in childhood often correlates with hypertension in early adulthood, thereby supporting the need to track blood pressure in children (Simons-Morton *et al.,* 1997; Lauer & Clarke, 1989) Furthermore, South African adult blacks are becoming heavily affected by increases in hypertension levels (van Rooyen *et al.,* 2000; Opie & Seedat, 2005) and in the North-West Province of South Africa this ranges from 14% to 33% in urban and rural blacks (van Rooyen *et al.,* 2000).

Statistics from both developed and developing countries suggest that the prevalence of childhood and adolescent obesity has increased substantially in the last few decades and possibilities are that this trend will continue (World Health Organization, 1999). This is a major public health concern as obesity in adolescence is associated with a wide range of conditions and metabolic abnormalities including elevated BP (Freedman, Dietz, Srinivasan & Berenson, 1999a). It is suggested that the effect of obesity on BP levels in adolescence may be related to accumulation of abdominal fat that occurs around the time of puberty. A study by Retnakaran, Hanley, Connelly, Harris and Zinman (2005) revealed a significant relationship between smoking and drinking status with blood pressure. However, Siervogel, Wisemandle, Maynard, Guo, Chumlea and Towne (2000) reported no association between smoking, alcohol intake and overweight except that in males the association approached significance.

Although several cut-off points have been used to identify overweight/obesity during childhood and adolescence (Reilly, 2002), in adults, a continuum of risk (towards development of CVD and other chronic diseases of lifestyle) associated with an increase in body mass index (BMI) cut-off points have been researched extensively (Willett *et al.,* 1995). They are widely used in screening, comparing populations and examining trends within populations (Popkin, Richards & Monteiro, 1996). However, in children and adolescents the variation of BMI with age has attracted criticisms about its widespread usage (Taylor, Jones, Williams & Goulding, 2000). The International Obesity Task Force has endorsed BMI as a measure of reasonable fatness in children and adolescents (Bellizzi & Dietz, 1990), resulting in Cole, Bellizzi, Flegal & Dietz (2000) deriving age- and sex-specific cut-off points for overweight and obesity in children and adolescents using multi-national data, which have since been recommended for international use by the World Health Organization (WHO) (1999).

Even though other anthropometric indicators such as subscapular skinfold (SSKF) (Freedman *et al.,* (1999b), waist-hip ratio (WHR) (Yusuf, et al, 2005) and waist circumference (WC) (Lurbe, Alvarez & Redon, 2001) have been shown to be associated with CVD risk factors, there are conflicting data regarding the best anthropometric markers for examining the association between elevated BP and body fat (Freedman *et al.,* 1999b; Lurbe *et al.,* 2001).

It is a well established finding that both increased blood pressure and obesity are the most common risk factors for chronic diseases of lifestyle and knowledge about these risk factors shows that even in adolescence some health indicators are important in the development of high BP and overweight in later life (Lauer & Clarke, 1989; Lauer et al., 1991). Several studies have been carried out in developed countries focusing on these risk factors in both children and adolescents but data from developing countries like South Africa are very limited (Monyeki, Kemper & Makgae, 2006). This study, therefore aimed at investigating the relationship between BP, measures of body composition and lifestyle factors (smoking and drinking) as well as determine which measure of obesity is strongly associated with BP in a group of adolescent township children. This findings could help in detecting risk factors for cardiovascular diseases at an early age so as to make early intervention possible.

Materials and Methods

Study design and subjects

This cross-sectional research forms part of the multi-disciplinary Physical Activity in Youth Study (PLAY) carried out on a group of high school children in the North-West Province of South Africa. PLAY was a study aimed at assessing the physical activity pattern of children and factors that affect these activity patterns. Two township schools were selected from a total of five schools. Grade 8 children in the selected schools were invited to participate in the study. The aims and procedures of the study were explained to both the children and their parents who subsequently signed informed consent forms before the children took part in the study. The provincial department of education and school principals also gave permission for the study to be undertaken at the two schools while the study protocol was approved by the Ethics Committee of the North-West University (project number 04M01).

Three-hundred and eighteen grade 8 black adolescents voluntarily participated in the study, out of the total group the 336 (94.6% of the initial group) gave their consent to participate. The children were transported from their schools to the university where the measurements were conducted and after completion of the measurements they were transported back to their schools. Complete data on BP and anthropometric measurements were available on 307 (174 girls; 133 boys) children representing 91.4% of the initial group. From this group, data on smoking and drinking habits were obtained from 138 children representing 45% of the studied group. The reduction in numbers was as a result of the lifestyle habits being taken retrospectively (after the initial measurements of anthropometry and blood pressure were done) as such some children did not complete the questionnaires. The adolescents answered questions about cigarette smoking and alcohol consumption individually. In order to encourage honest answers they were reassured that nobody (parents and/or teachers) would have access to the information about their smoking and drinking habits. Subjects who drank alcoholic beverages (liquor, beer, wine and traditional beer) at least once a month were regarded as drinkers. Children who smoked at least one cigarette per week were considered to be smokers.

Anthropometry

Anthropometric measurements were taken by trained anthropometrists, with the subjects barefooted and also in their underwears. Boys and girls' anthropometric measurements were taken separately in private rooms. Weight was measured on a portable electronic scale (Precision Health Scale, A&D Company, Saitama, Japan) and height was measured with a stadiometer (IP 1465, Invicta, London, UK), with the subjects standing upright with their heads in the Frankfort plane. Body mass index (BMI) was calculated as weight divided by height squared (kg/m^2) and the subjects were classified according to the age- and sex-adjusted BMI cut-offs described by Cole *et al.* (2000).

Waist circumference (WC) was measured, to the nearest 0.1 cm with a 7-mm-wide flexible steel tape (Lufkin, Cooper Tools, Apex, NC), at the midpoint between the lower rib margin and the iliac crest. The hips were measured to the nearest 0.1 cm at maximum width of the buttocks. Waist-hip ratio (WHR) was calculated from waist and hip circumferences. Skinfolds measurements, triceps (TSKF) and subscapular (SSKF) skinfolds, were measured to the nearest 0.5 mm using a Harpenden calliper according to the methods of the International Society for the Advancement of Kinanthropometry (ISAK). The Pearson product moment correlation coefficient (r) were used to test for the reliability for each anthropometric variable. The mean intra-tester r-values for anthropometric components ranged from r= 0.89 to r= 0.92, respectively.

The proportion of body fat on the trunk relative to that of the limbs was used as an indicator of the central body fat distribution by using the following equations (Cameron & Getz, 1997; Kemper, Post, Twisk & van Mechelen, 1999).

$$\text{S/T ratio} = \frac{\text{Subscapular skinfold thickness}}{\text{Triceps skinfold thickness}} \qquad (1)$$

$$\text{S/ST ratio} = \frac{\text{Subscapular skinfold thickness}}{\text{Subscapular + Triceps skinfold thicknesses}} \quad (2)$$

Body composition

Body composition was evaluated using air displacement plethysmography and the BODPOD scale (Life Measurement, Inc, Concord, CA). Measurements were performed according to manufacturer's instructions and recommendations, with each subject wearing a tight-fitting swimsuit and swim cap. The assessment of body composition using the BODPOD is a reliable and valid method for use in children’s studies (Fields, Goran & McCrory, 2002).

Maturity

Sexual maturity was assessed by using the 5-stage Tanner scale for breast development in females and for pubic hair in males (Tanner, 1962).

Blood pressure measurement

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured following standardised protocols of the National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents (2004). A mercury sphygmomanometer (Tycos, USA) of appropriate cuff size (covering 80 to 100% of the arm circumference) and a stethoscope were used. The same equipment was used on all children who were asked to sit quietly for 5 minutes before BP was measured. To ensure reliability and validity the measurements were done twice by four trained cardiovascular physiologists with the riva rocci method and the average of the two readings was taken for the purpose of analysis. The white coat effect was minimized since the children were familiar with the methods in taking blood pressure measurements. Blood pressure was classified according to the recommendations of National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents (2004). Hypertension was defined as SBP and/or DBP $\geq 95^{th}$ percentile and high BP (pre-hypertension) as SBP and/or DBP $\geq 90^{th}$ percentile but $<95^{th}$ percentile; while normal BP status was defined as SBP and DBP $< 90^{th}$ percentile for height for age.

Statistical analysis

Data were analysed using SPSS version 14.0 statistical package. Descriptive statistics- median and inter-quartile ranges for continuous variables and frequencies for categorical parameters were computed to describe the data. Non-parametric t-test was used to test for significant differences between two continuous variables and Chi-Square (X^2-) test for examining differences between categorical variables. Regression analysis was carried out separately for both girls and boys to examine the independent effects of various measures of body composition (age, height, WC, TSKF, SSKF, and percent body fat) on SBP and DBP and also adjusting for lifestyle factors (smoking and drinking).

Results

Table 1 presents the median (interquartile ranges) for the anthropometric characteristics of the studied children. At ages 12-14 years, girls were significantly heavier than the boys with high BMI at ages 14 and 16 years of age. From 15 years of age boys were significantly taller than girls. In general girls had higher hip circumference, TSKF and SSKF values at all ages. Throughout the different ages boys recorded significantly higher values for WHR. Girls had significantly higher percent body fat and fat mass within all the age groups.

Prevalence of hypertension and overweight/obesity

With respect to BP levels 21.3% of the girls and 33.1% of the boys were pre-hypertensive/hypertensive respectively (i.e. SBP and/or DBP $\geq 90^{th}$ percentile). There was, no gender differences in blood pressure levels (both SBP and DBP) as age increased (Figures 1 and 2). However, in both girls and boys there was a significant increase in the proportions of children who were pre-hypertensive/hypertensive with age ($X^2_{\text{Linear trend}} = 10.44$, p=0.001; $X^2_{\text{Linear trend}} = 14.89$, p<0.001 for girls and boys respectively).

Twenty-five children (8.1%) from the total population were overweight/obese according to the International Obesity Task Force (IOTF) cut-off points (Cole *et al.,* 2000). The prevalence of overweight/obesity in girls was significantly higher than that of boys in all age groups (X^2=6.08, p=0.048) (Table 2). Of all the children 6 (1.95%) were pre-hypertensive/hypertensive and obese/overweight, representing 24% of the overweight/obese children. Furthermore, there was no difference in both SBP and DBP when the children were divided into normal and overweight/obese based on their BMI levels (data not shown).

Association between BP and measures of body composition, lifestyle habits and BP

Nine of the twelve anthropometric indicators measured were significantly related with blood pressure. When data was adjusted for age and Tanner stage it was found that in girls SBP was positively associated with weight, WC, TSKF, percent body fat and fat mass. Furthermore, DBP in girls was positively associated with BMI and WC. In boys weight, height, WC, HC, SSKF and fat mass were positively associated with SBP and no associations with DBP were observed (Tables 3 and 4).

Table 1: Anthropometric measurements of the children by age and gender (medians (inter-quartile ranges) and gender differences)

Variable	Gender	Age (years) 12-13	14	15	16	17-19	Total
	F	44	50	31	25	24	174
Subject	M	18	47	24	22	22	133
Weight (kg)	F	43.20 (10.96)	43.20 (9.00)	44.70 (8.90)	50.10 (11.30)	47.50 (13.29)	45.10 (10.20)
	M	38.70 (9.39)*	40.01 (10.72)*	47.72 (11.66)	49.46 (10.42)	51.81 (8.63)	43.90 (13.30)
Height (m)	F	1.53 (0.06)	1.53 (0.05)	1.55 (0.06)	1.52 (0.09)	1.59 (0.08)	1.54 (0.08)
	M	1.51 (0.07)	1.54 (0.09)	1.62 (0.10)**	1.66 (0.09)***	1.66 (0.10)***	1.58 (0.15)***
BMI (kg/m^2)	F	18.27 (4.08)	18.41 (3.26)	18.62 (3.67)	20.98 (5.49)	20.27 (5.72)	18.93 (3.95)
	M	17.01 (3.78)	17.26 (3.42)**	18.16 (2.53)	17.98 (3.69)**	18.59 (2.99)	17.89 (3.03)***
WC (cm)	F	61.50 (6.20)	61.73 (8.00)	62.50 (8.10)	66.00 (10.43)	65.10 (6.30)	62.50 (7.90)
	M	60.40 (6.00)	61.65 (5.58)	64.70 (6.06)	64.30 (4.64)	65.62 (4.24)	63.50 (6.00)
Hip circumference (cm)	F	84.50 (10.25)	83.85 (9.83)	84.60 (11.05)	90.00 (14.95)	91.15 (13.50)	85.00 (11.24)
	M	75.20 (9.20)***	76.60 (9.50)***	81.30 (8.04)*	81.95 (7.05)***	83.00 (5.88)***	79.50 (9.30)***
WHR	F	0.730 (0.04)	0.74 (0.07)	0.73 (0.06)	0.74 (0.07)	0.72 (0.07)	0.73 (0.06)
	M	0.81 (0.06)***	0.79 (0.05)***	0.80 (0.04)***	0.78 (0.07)***	0.78 (0.06)***	0.79 (0.05)***
TSKF (cm)	F	12.50 (9.30)	11.55 (5.63)	12.20 (8.15)	12.90 (7.70)	13.50 (7.00)	12.45 (6.70)
	M	9.30 (4.70)*	7.80 (5.50)***	7.90 (5.20)***	7.30 (3.28)***	7.20 (3.30)***	7.65 (4.70)***
SSKF (cm)	F	9.20 (4.80)	8.75 (3.16)	8.60 (3.90)	9.40 (6.50)	10.60 (4.60)	9.00 (4.28)
	M	6.20 (2.50)***	6.00 (2.33)***	6.60 (1.95)***	6.25 (0.85)***	7.20 (1.33)***	6.30 (2.10)***
S/T ratio	F	0.75 (0.25)	0.75 (0.22)	0.70 (0.31)	0.79 (0.22)	0.74 (0.24)	0.75 (0.23)
	M	0.66 (0.22)	0.79 (0.28)	0.87 (0.32)	0.89 (0.21)	0.98 (0.40)	0.85 (0.33)*
S/ST	F	0.43 (0.08)	0.43 (0.07)	0.41 (0.10)	0.44 (0.07)	0.43 (0.08)	0.43 (0.08)
	M	0.39 (0.08)	0.44 (0.09)	0.46 (0.09)	0.47 (0.06)	0.49 (0.10)*	0.46 (0.10)**
%BF	F	26.20 (9.05)	28.25 (11.65)	26.70 (8.70)	30.40 (9.70)	28.40 (12.95)	27.60 (9.12)
	M	21.30 (4.65)*	19.90 (6.60)***	17.40 (5.65)***	16.70 (6.20)***	14.30 (7.05)***	18.15 (6.50)***
Fat mass	F	10.01 (6.66)	11.25 (5.93)	12.12 (6.28)	14.96 (10.10)	14.65 (9.03)	12.18 (6.73)
	M	7.82 (3.43)***	7.30 (4.47)***	7.99 (2.76)***	8.94 (4.45)***	7.10 (3.66)***	7.86 (3.64)***

BMI = body mass index, WC= waist circumference, WHR = waist-hip ratio TSKF = triceps skinfold SSKF =subscapular skinfold, %BF= percent body fat, *significant differences between boys and girls, M-male; F-female. *p≤0.05, **p≤0.01, ***p≤0.00Z. Figures in brackets are medium values.

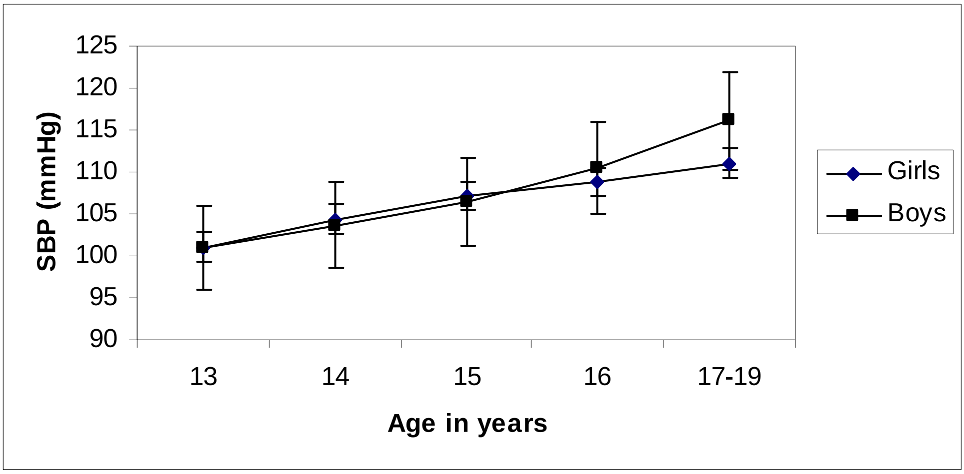

Figure 1: SBP of the adolescent children aged 13-19 years (Mean ± SEM).

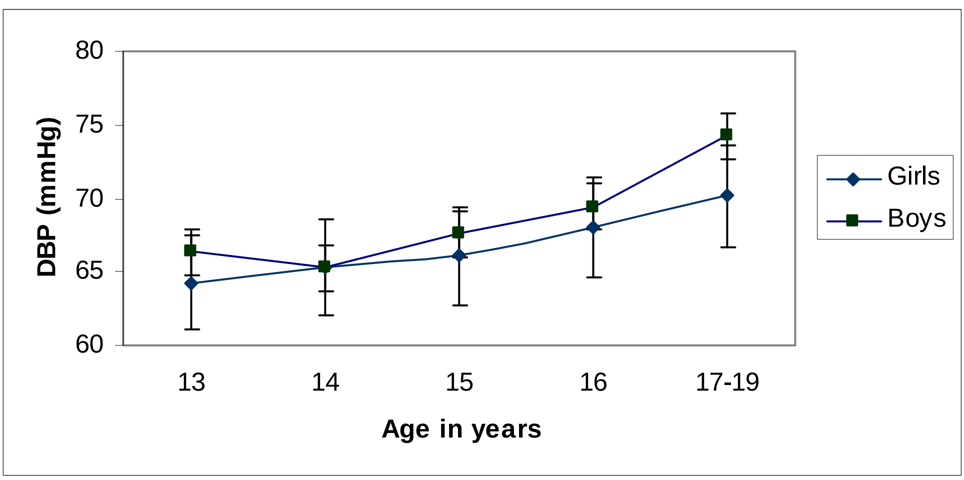

Figure 2: DBP of the adolescent children aged 13-19 years (Mean ± SEM).

Table 2: Prevalence of hypertension and overweight/obesity in adolescents aged 12-19 years

Age (years)	Total girls and boys in different age groups		Pre-Hypertensive/ Hypertensive n (%)		Overweight/obese n (%)	
	Girls	Boys	Girls	Boys	Girls	Boys
12-13	44	19	5 (11.4%)	2 (10.3%)	6 (13.6%)	1 (5.6%)
14-	50	46	8 (16.0%)	16 (13.0%)	5 (10.0%)	3 (6.7%)
15-	31	24	7 (22.6%)	6 (25.0%)	1 (3.1%)	0 (0%)
16-	25	22	6 (24%)	9 (40.9%)	6 (24.0%)	1 (4.5%)
17-19	24	22	11 (45.8%)	11 (50.0%)	2 (8.3%)	-
Total	174	133	37 (21.3%)	44 (33.1%)	20 (11.5%)	5 (3.8%)

Table 3: Association between SBP and DBP and selected anthropometric indicators in girls aged 12-19 years (n=174)

	Unadjusted correlation coefficients		Age and Tanner stage- adjusted correlation coefficients	
	SBP	DBP	SBP	DBP
Age (years)	0.264, p<0.001	0.186, p=0.014	-	-
Weight (kg)	0.312, p<0.001	0.294, p<0.001	0.199, p=0.024	0.165, p=0.062
Height (m)	0.194, p=0.010	0.185, p=0.015	0.092, p=0.298	0.125, p=0.157
Body mass index (kg/m^2)	0.257, p=0.001	0.240, p=0.001	0.168, p=0.058	0.119, p=0.018
Waist circumference(cm)	0.323, p<0.001	0.329, p<0.001	0.231, p=0.008	0.209, p=0.017
Hip circumference (cm)	0.286, p<0.001	0.296, p<0.001	0.141, p=0.111	0.128, p=0.120
Waist-to-hip ratio	-0.012, p=0.874	-0.024, p=0.752	0.077, p=0.384	0.061, p=0.491
Triceps skinfold (cm)	0.283, p<0.001	0.233, p<0.001	0.279, p=0.001	0.164, p=0.063
Subscapular skinfold (cm)	0.186, p=0.014	0.160, p=0.036	0.148, p=0.094	0.091, p=0.303
S/T ratio	-0.045, p=0.561	-0.031, p=0.685	-0.131, p=0.138	-0.070, p=0.429
S/ST ratio	-0.099, p=0.196	-0.066, p=0.389	-0.165, p=0.062	-0.076, p=0.390
Percentage body fat (%)	0.300, p<0.001	0.206, p=0.017	0.264, p=0.003	0.155, p=0.079
Fat mass (kg)	0.304, p<0.001	0.224, p<0.009	0.250, p=0.004	0.164, p=0.063

S/T ratio =subscapular-triceps skinfold ratio S/ST ratio = subscapular-subscapular + triceps skinfolds ratio.

There were no differences in anthropometric and blood pressure measurements between children with data on smoking and drinking habits and those without the data (data not shown). Their correlations were the same and in the subset of children with smoking and alcohol intake data after adjusting for both factors in girls, the correlations between weight and SBP and that between BMI and DBP were lost. In boys however, after adjusting for the confounders, an association between S/T ratio (r=0.497, p<0.001) and S/ST ratio (r=0.469, p=0.001) and SBP were observed. Furthermore, there were no differences in the percentage overweight/obese and the number with elevated BP between the two groups.

Table 4: Association between SBP and DBP and selected anthropometric indicators in boys aged 12-19 years (n=133)

	Unadjusted correlation coefficients		Age and Tanner stage- adjusted correlation coefficients	
	SBP	DBP	SBP	DBP
Age (years)	0.417, p<0.001	0.353, p<0.001	-	-
Weight (kg)	0.469, p<0.001	0.335, p<0.001	0.379, p<0.001	0.179, p=0.064
Height (m)	0.471, p<0.001	0.361, p<0.001	0.322, p=0.001	0.146, p=0.132
Body mass index (kg/m^2)	0.317, P,0.001	0.203, p=0.019	0.280, p=0.003	0.129, p=0.183
Waist circumference(cm)	0.364, p<0.001	0.231, p=0.008	0.295, p=0.002	0.121, p=0.214
Hip circumference (cm)	0.334, p<0.001	0.186, p=0.33	0.341, p<0.001	0.103, p=0.287
Waist-to-hip ratio	-0.040, p=0.652	-0.002, p=0.982	-.0120, p=0.216	0.021, p=0.832
Triceps skinfold (cm)	-0.017, p=0.854	-0.148, p=0.091	0.082, p=0.398	-0.090, p=0.354
Subscapular skinfold (cm)	0.290, p=0.001	0.095, p=0.279	0.316, p=0.001	0.064, p=0.512
S/T ratio	0.286, p=0.001	0.301, p<0.001	0.161, p=0.097	0.160, p=0.098
S/ST ratio	0.304, p<0.001	0.300, p<0.001	0.177, p=0.067	0.172, p=0.074
Percentage body Fat (%)	-0.086, p=0.368	-0.239, p=0.011	0.058, p=0.548	-0.145, p=0.134
Fat mass (g)	0.198, p=0.036	-0.044, p=0.646	0.246, p=0.010	-0.027, p=0.784

S/T ratio =subscapular-triceps skinfold ratio S/ST ratio = subscapular-subscapular + triceps skinfolds ratio

Of the children who admitted to smoking (5.7%), only one had elevated BP (data not shown). Twenty-nine (21%) children were drinkers (15.2% in girls and 27.1% in boys) and of these drinkers six (4.3% of the total sub-sample making 20.7% of the drinkers) had elevated BP (pre-hypertensive/hypertensive) (data not shown). Of the children who smoked, only one was a girl. The median age of starting to smoke was 15 years (13-17 interquartile range) while the median daily tobacco consumption was 6 cigarettes per day (2-10 interquartile range).

Table 5 shows the results of the linear regression analyses on independent variables: age, height, WC, TSKF and SSKF and percent body fat on SBP. The analysis reveals that in girls, age, WC and TSKF are independent markers of SBP. The low value of the adjusted R^2 (17%) in girls indicates that the variables explained only a small percentage of the variation in SBP. In boys the model showed that height, TSKF and SSKF were independent markers of SBP, with this model explaining 29% of the variation in SBP. Looking at the sub-group of children whose smoking and drinking data was available, the two factors did not affect the outcome of the models.

Table 5: Linear regression analysis of selected body fat composition measures on SBP stratified for gender

Variables	Girls		Boys	
	β-coefficient	p	β-coefficient	p
Age	0.198	0.022	0.115	0.262
Height	0.198	0.172	0.115	0.009
Waist circumference	0.109	0.022	0.169	0.226
Triceps skinfold	0.308	0.048	-0.336	0.040
Subscapular skinfold	-0.308	0.055	0.301	0.006
Percent body fat	0.193	0.128	0.098	0.474
	R= 0.457, R^2= 0.170, SEE = 11.27, p <0.001		R= 0.572, R^2= 0.289, SEE = 10.69, p <0.001	

*SEE= standard error of the estimate

Discussion

This study presents baseline data on the association between BP, measures of body composition and lifestyle factors in black South African township adolescents. The prevalence of pre-hypertension/hypertension was 23.1% (23.1% and 33.1% in girls and boys respectively) while hypertension (SBP and/or DBP ≥ 95th percentile) alone was present in 10.1% (9.2% and 11.3% of the girls and boys respectively). Overweight/obesity on the other hand was found in 8.1% of the children (11.5% in girls and 3.8% in boys). In the overweight/obese children 24%, were pre-hypertensive/hypertensive. These findings support those of a study done in pre-adolescent rural South African children where it was found that hypertension and overweight start to manifest themselves from an early age (Monyeki, Kemper & Makgae, 2006). This rapid increase in prevalences of CVD risk factors in children has been linked to dramatic changes in culture and lifestyle experiences. It has been suggested that, in concert with underlying genetic susceptibility, the adoption of dietary habits and sedentary lifestyles typical of Western populations has led to the proliferation of vascular and metabolic risk factors and diseases (Hanley *et al.,* 2000). Among the lifestyle factors are smoking and drinking which were reported by 5.7% and 21% of the children respectively.

Indeed, it is recommended that children with elevated BP be given special attention, by looking at other risk factors such as their diet (Simons-Morton & Orbazanek, 1997; Schutte *et al.,* 2003), physical activity, smoking (Kavey *et al.,* 2003) and biological markers of chronic diseases of lifestyle (Gaskin, Walker, Forrester & Grantham-McGregor, 2000; Schutte *et al.,* 2003a), as previous researchers have found that children with elevated BP are at increased risk of developing CVD related abnormalities in adulthood (Magalhães *et al.,* 1998).

It is recommended that elevated BP must be confirmed on repeated visits before characterising an individual as hypertensive (National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents, 2004), and a precise classification has to be based on measurements taken over weeks or months (Morgenstern, 2002; National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents, 2004). Thus a follow-up on the present pre-hypertensive/hypertensive adolescents might have yielded a different scenario as portrayed in Anand and Tandon (1996) study. However, it has to be noted that the purpose of this study was to assess the extent of elevated BP and not as a means of diagnosing hypertension in these adolescents.

Previous reports have explored the relationship between BP and measures of body composition, but there is still paucity of data on this relationship in black South African township adolescents (Schutte *et al.,* 2003b; van Rooyen *et al.,* 2005; Monyeki *et al.,* 2006). Unlike what has been previously reported (Okasha, McCarron, McEwen & Davey Smith, 2000; Al-Sendi, Shetty, Musaiger & Myatt, 2003), we found no gender related differences in BP measures in the studied adolescents, though trend analysis revealed that the proportions of pre-hypertensive/hypertensive children increased when children are getting older. However, the relationship between age and both SBP and DBP in boys was moderately higher than in girls, suggestive of sex-related patterns of growth and the observed more rapid increase in height in boys than girls as evidenced from age 15 years in the present study is supportive of this. The increase in height with age in boys followed the same trend as the increase in SBP and DBP with age, whereas in girls the differences between weight, SBP and DBP between the different age groups were smaller.

The study also revealed several anthropometric parameters related to SBP in both girls (weight, WC, TSKF, percent body fat and fat mass) and boys (weight, height, BMI, WC, hip circumference, SSKF and fat mass). Since most of these variables are highly correlated, we entered, into a linear regression analysis, only variables that showed the strongest correlation with SBP and/or those that have been previously reported to be of importance in explaining SBP variations in children and adolescents (Freedman *et al.,* 1999a; Lurbe *et al.,* 2001; Monyeki *et al.,* 2006). Regression analysis showed that in girls, age, WC and TSKF were predictive markers of SBP accounting for 15% of the variance in SBP while in boys, height, TSKF and SSKF were predictive markers of SBP.

Entering smoking and drinking status of the children into the model the results showed that these were not related to SBP. This contradicts previous reports where these two lifestyle factors were related to BP in both adolescents and adults (Retnakaran *et al.,* 2005). A possible reason for not finding any significant association in the present study might be that most of the children were still experimenting with the usage of these drugs as evidenced by the low amounts of cigarettes smoked. Use of these substances may take a few years to cause permanent changes in the vascular wall and due to the relatively short period of use of these substances no effects may be visible at this early stage. But this does highlight the importance of early intervention to modify lifestyle habits in adolescent children, a suggestion reiterated by most researchers across the globe (Retnakaran *et al.,* 2005). On the other hand, no relationships between measures of body composition and DBP were observed.

In girls, however, peripheral fat (as measured by TSKF) was strongly and positively related to SBP while in boys centrally located fat (as measured by SSKF) showed a stronger association with SBP, this is also an interesting result which compare well with existing literature on adults. It is worth noting that in boys TSKF was an independent negative predictor of SBP, a finding which might have resulted from gender-related differences in growth which occurs during puberty. In addition we found that when the children were getting older there was a steady decrease in TSKF.

The S/T ratio is a widely used indicator for fat patterning, and in children it has been shown to be related to hypertension (Monyeki *et al.,* 2006). However, in this study no association was found between S/T ratio and SBP, a finding previously reported by others (Al-Sendi *et al.,* 2003). The same was true for S/ST ratio and SBP indicating that these measures of fat patterning may not be good indicators of body fat content in this age group.

In South Africa, several studies have reported that obesity amongst black women is the highest (South African Health Review, 1998; Pouane *et al.,* 2002; Case & Mendez, 2009). The present study shows that WC in girls is strongly associated with SBP, whereas with boys more “muscular”/ bone mass data such as height is associated with SBP. This might already show the discrepancy between males and females from a young age, and might be an early prediction of future obesity in these female adolescents which may result in the known effects of adult obesity.

More emphasis has been given to the use of WC as a measure of central adiposity in both adults; and children and adolescents (Taylor *et al.,* 2000). This was based on the said reflection of WC as an indicator of abdominal fat accumulation rather than WHR (Okasha *et al.,* 2000; Taylor *et al.,* 2000). This may also be due to the observation that in growing children (as it happens during pubertal growth spurt) the hip circumference offers more of a reflection of changes in bones and muscles than changes in fat. Our finding that WC and not WHR in both girls and boys was positively associated with SBP supports the above speculations. Furthermore, this supports the widely held notion that fat distribution is related to CVD risks, of which high BP is an important factor in adolescents (Simons-Morton *et al.,* 1997; Lurbe *et al.,* 2001). Our findings are congruent with those of Schutte *et al.* (2003) who found no association between WHR and BP in 10-15 year old black children in the North-West Province.

The present findings of a high percentage of adolescents with pre-hypertension/hypertension (21.3% in girls and 33.1% in boys) should be seen as a major concern with respect to this population's future health status as high BP levels in children and adolescents have been shown to track (persist) well into adulthood independent of BMI levels (South African Health Review, 1998; Schutte *et al.,* 2003). Conversely elevated BMI in children and adolescents is also reported to track into adulthood, presenting itself as another risk factor for development of CVDs in later life (Lauer *et al.,* 1991; Kelder *et al.,* 2002; Burke, Beilin, Dunbar & Kevan, 2004). As such the positive relationship between SBP and BMI observed in this study (though not significant in girls) poses a major public health problem in this population known to be undergoing rapid epidemiological and nutritional transition (Vorster, Venter, Wissing & Margetts, 2005).

However, this study has some limitations which are: 1) the cross-sectional nature of the study which limits the ability to address causality between factors reported herein and furthermore, nothing can be said about the duration of either elevated blood pressure or overweight/obesity in these adolescents; 2) because of geographic, socioeconomic, cultural and ethnic differences among regions in the country, the results can not be generalized to all black South African adolescents.

Nevertheless, findings in this study of a high prevalence of prehypertension/hypertension (21.3% in girls and 33.1% in boys) and the significant associations between peripheral fat in girls and centrally located fat in boys with SBP show the need for preventive measures to be taken early in life. Kelder *et al.* (2002) have shown that anthropometric variables show the strongest tracking, suggesting that it is difficult to alter the pattern of overweight that exist as early as 8 or 9 years of age. With respect to BP the day-to-day variations and its dependency on various other factors makes it unlikely to observe strong levels of tracking but its long-term effects are not to be ignored. Magalhaes *et al.* (1998) have found that BP in children and adolescents served as a good marker for familial aggregation of metabolic CVD risk factors as such supporting this assumption. In addition among adolescents and young adults high BP is associated with the presence of early atherosclerotic lesions (Retnakaran *et al.,* 2005). Based on the above findings our study perpetuate the need for introducing primary intervention at an early stage, as well as undertaking follow-up studies to investigate if any ethnic differences might be present, especially for this population undergoing nutritional transition.

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